

Article

The Power of Symmetries in Nuclear Structure and Some of Its Problems

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Abstract: A review of several classical, algebraic models in nuclear structure physics, which use symmetries as an important tool, are presented. After a conceptual introduction to group theory, a selection of models is chosen to illustrate the methods and the power of the usage of symmetries. This enables us to describe very involved systems in a greatly simplified manner. Some problems are also discussed, when ignoring basic principles of nature, such as the Pauli exclusion principle. We also show that occasionally one can rescue these omissions. In a couple of representative models, applications of symmetries are explicitly applied in order to illustrate how extremely complicated systems can be treated. This contribution is meant as a review of the use of algebraic models in nuclear physics, leading to a better understanding of the articles in the same special volume.

Keywords: algebraic models; nuclear physics; group theory



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1. Introduction

Symmetries play a primordial role in all fields of physics, just think of the cyclic variables in classical mechanics, which imply conserved generalized momenta. A cyclic variable thus exhibits a symmetry of the Lagrangian. Alternatively, take Noether's theorem, which allows us to identify continuous symmetries, so it is essential not only in field theory. The rotational symmetry is one example of a continuous symmetry and the corresponding conserved quantum number is the angular momentum, which is in most models and theories a good quantum number.

A symmetry is related to a transformation that leaves the Lagrangian and Hamiltonian invariant, or in other words, that the Hamiltonian commutes with the operator, which generates the symmetry transformation.

Nuclear physics is no exception; here, the Hamiltonian commutes with the generators of the angular momentum group. However, there is more. The use of symmetries in nuclear physics is nearly as old as quantum mechanics. Remember the seminal work in 1931 of H. Weyl [1]. The first noticeable application of symmetries in nuclear physics is the shell model [2], recognizing that the special unitary group $SU(3)$ plays a central role. We will see in Section 2 that this is a trivial consequence, as it is nothing but counting the degrees of freedom of a system correctly. In fact, in Section 2, I will present a basic introduction to symmetry, also known as group theory (a less attractive word), resuming mainly well-known methods and facts that are very useful in understanding all models in nuclear theory based on symmetry. The content of Section 2 may seem to be too trivial for most physicists accustomed to the use of symmetry. This is intentional, because some points will be stressed that are often easily overlooked and taken as guaranteed.

Several years after the presentation of the shell model, J.P. Elliott [3,4] proposed a $SU(3)$ model for the description of deformed nuclei and we will see how this approach taught us to also describe nuclear clusters. Another advantage is that the method of using symmetry groups, such as the $SU(3)$, provides very simple formulas for the spectrum of a nucleus.

Symmetries In Nuclear Structure

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A decorative graphic consisting of a red circular shape with a white center, partially obscured by a white horizontal bar.

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Symmetries in Nuclear Structure K. Abrahams, K. Allaart, A. E. L. Dieperink, 2013-11-21 The 1982 summer school on nuclear physics organized by the Nuclear Physics Division of the Netherlands Physical Society was the fifth in a series that started in 1963 The number of students attending has always been about one hundred coming from about thirty countries The theme of this year's school was symmetry in nuclear physics This book covers the material presented by the enthusiastic speakers who were invited to lecture on this subject We think they have succeeded in presenting us with clear and thorough introductory talks at graduate or higher level The time schedule of the school and the location allowed the participants to make many informal contacts during many social activities ranging from billiards to surf board sailing We hope and expect that the combination of a relaxed atmosphere during part of the time and hard work during most of the time has furthered the interest in and understanding of nuclear physics The organization of the summer school was made possible by substantial support from the Scientific Affairs Division of the North Atlantic Treaty Organization the Netherlands Ministry of Education and Science the Foundation Physica and the Netherlands Physical Society *Group Symmetries in Nuclear Structure* J. Parikh, 2012-12-06 This book is the result of a graduate level special topics course I gave at the University of Rochester in 1970 The purpose of the course was to discuss as far as possible all known symmetries in nuclei with special emphasis on dynamical symmetries Since there was no comprehensive account of this subject in the literature I was encouraged to write a review based on my lecture notes The end result is the present volume Like the course the book is intended mainly for graduate students and research workers in nuclear physics The only prior knowledge required to follow the book is graduate level quantum mechanics and nuclear physics and hence I believe that it can be useful to both experimental and theoretical nuclear physicists In addition the book should prepare a student to read the latest literature on the subject and also train him to do group theoretic work in nuclear physics The organization of the material in the book is described in Chapter 1

Proceedings of the Highly Specialized Seminar on Symmetries in Nuclear Structure Andrea Vitturi, R. Casten, 2004 The Highly Specialized Seminar on Symmetries in Nuclear Structure held in Erice Italy in March 2003 celebrated the career and the remarkable achievements of Francesco Iachello on the occasion of his 60th birthday Since the development of the interacting boson model in the early 1970s the ideas of Iachello have provided a variety of frameworks for understanding collective behaviour in nuclear structure founded on the concepts of dynamical symmetries and spectrum generating algebras The original ideas which were developed for the description of atomic nuclei have now been successfully extended to cover spectroscopic behaviour in other fields such as molecular or hadronic spectra More recently the suggestion by Iachello of critical point symmetries to treat nuclei in shape phase transitional regions has opened an exciting new front for both theoreticians and experimentalists The talks presented at the meeting covered many of the most active forefront areas of nuclear structure as well as other fields where ideas of symmetries are being explored Topics in nuclear

structure included extensive discussions on dynamical symmetries critical point symmetries phase transitions statistical properties of nuclei supersymmetry mixed symmetry states shears bands pairing and clustering in nuclei shape coexistence exotic nuclei dipole modes and astrophysics among others In addition important sessions focused on talks by European laboratory directors or their representatives outlining prospects for nuclear structure and the application of symmetry ideas to molecular phenomena Finally a special lecture by Nobel laureate Alex Mueller on s and d wave symmetry in superconductors presented a unique insight into an allied field The proceedings have been selected for coverage in Index to Scientific Technical Proceedings ISTP ISI Proceedings Index to Scientific Technical Proceedings ISTP CDROM version ISI Proceedings CC Proceedings Engineering Physical Sciences Symmetries and Nuclear Structure Richard A. Meyer,Vladimir Paar,1987 **Symmetries in Nuclear Structure** K. Abrahams,K. Allaart,A. E. L. Dieperink,2014-09-01 *Symmetries in Nuclear Structure (Volume 93/B)*. Abrahams K.,1983 **Symmetries in Atomic Nuclei** Alejandro Frank,Jan Jolie,Pieter van Isacker,2008-12-17 Symmetries in Atomic Nuclei aims to present an overview of recent applications of symmetry to the description of atomic nuclei Special care is given to a pedagogical introduction of symmetry concepts using simple examples After a historical overview of the applications of symmetry in nuclear physics progress in the field during the last decade is reviewed Special emphasis is put on the introduction of neutron proton and boson fermion degrees of freedom Their combination leads to a supersymmetric description of pairs and quartets of nuclei Both theoretical aspects and experimental signatures of dynamical super symmetries are carefully discussed Case studies show how these symmetries are displayed by real atomic nuclei which have been studied experimentally using state of the art spectroscopy This book focuses on nuclear structure physics and has been written by active investigators in the field but its scope is wider and is intended for final year or post graduate students and researchers interested in understanding the power and beauty of symmetry methods in physics **Symmetries and Nuclear Structure** R. A. Meyer,Vladimir Paar,1987 Symmetries and Nuclear Structure ,1986 *Fundamental Symmetries and Nuclear Structure* J. N. Ginocchio,S. P. Rosen,1989 **Lectures on Group Symmetries in Nuclear Structure** Jitendra C. Parikh,1971 **Symmetries in Nuclear Structure** ,2004 *Symmetries in Nuclear Structure* ,1983 **Group Theory And Special Symmetries In Nuclear Physics - Proceedings Of The International Symposium** Joachim W Janecke,Jerry P Draayer,1992-06-16 Organized in honor of K T Hecht Professor of Physics at the University of Michigan for his frontier research in group theory and nuclear physics this symposium features papers by principal researchers who have contributed to the development and use of algebraic methods in nuclear physics The symposium aims to make a critical assessment of what has been accomplished since the seminal work of J P Elliott on the SU 3 model and to identify significant challenges and opportunities that lie in the future Topics include the SU 3 model and its noncompact Sp 3 R extension boson and fermion dynamical symmetry schemes pseudo spin and superdeformation cluster model configurations and calculations recent advances in vector coherent state theories quark

models for subnucleon degrees of freedom in nuclei and more **Symmetries in Nuclear Structure** Andrea Vitturi, Richard F. Casten, 2004 Annotation The Highly Specialized Seminar on Symmetries in Nuclear Structure held in Erice Italy in March 2003 celebrated the career and the remarkable achievements of Francesco Iachello on the occasion of his 60th birthday Since the development of the interacting boson model in the early 1970s the ideas of Iachello have provided a variety of frameworks for understanding collective behaviour in nuclear structure founded on the concepts of dynamical symmetries and spectrum generating algebras The original ideas which were developed for the description of atomic nuclei have now been successfully extended to cover spectroscopic behaviour in other fields such as molecular or hadronic spectra More recently the suggestion by Iachello of critical point symmetries to treat nuclei in shape phase transitional regions has opened an exciting new front for both theoreticians and experimentalists The talks presented at the meeting covered many of the most active forefront areas of nuclear structure as well as other fields where ideas of symmetries are being explored Topics in nuclear structure included extensive discussions on dynamical symmetries critical point symmetries phase transitions statistical properties of nuclei supersymmetry mixed symmetry states shears bands pairing and clustering in nuclei shape coexistence exotic nuclei dipole modes and astrophysics among others In addition important sessions focused on talks by European laboratory directors or their representatives outlining prospects for nuclear structure and the application of symmetry ideas to molecular phenomena Finally a special lecture by Nobel laureate Alex Mueller on s and d wave symmetry in superconductors presented a unique insight into an allied field Nuclear Structure, Reactions, and Symmetries Richard A. Meyer, 1986 Very Good No Highlights or Markup all pages are intact Dynamical Symmetries and Nuclear Structure Akito Arima, 1997 **Dynamical Symmetries in Nuclear Structure** ,1986 In recent years the concept of dynamical symmetries in nuclei has witnessed a renaissance of interest and activity Much of this work has been developed in the context of the Interacting Boson Approximation or IBA model The appearance and properties of dynamical symmetries in nuclei will be reviewed with emphasis on their characteristic signatures and on the role of the proton neutron interaction in their formation systematics and evolution 36 refs 20 figs **Study of Spinor Symmetries in Nuclear Structure** Serdar Kuyucak, 1982 **Fundamental Symmetries and Nuclear Structure** ,1989

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